Training and Verification for Risk Reduction on the New Classes of Missions at NASA's Jet Propulsion Laboratory

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Abstract—The focus on improving and increasing planetary exploration with lower cost missions and the unfortunate incidents of the not so distant past point to a need for risk reduction without budget inflation. To satisfy this need requires a robust program well founded in standardized practices with standards of performance. Standardized practices facilitate repeating successful projects without recreating all of the original work that led to the initial success. Standards provide a means to measure progress and gauge performance in relation to levels that result in success. By developing, within the Jet Propulsion Laboratory's (JPL) Mission Management Office (MMO), a core program of standardized training and verification practices and standards against which the implementation of these practices can be measured, we expect to provide an affordable resource for project risk reduction in key areas.

The importance of well prepared individuals, teams, and a Mission Operations System (MOS) as the cornerstone in improving the likelihood of success and reducing risk is the focus of our program. We address individual position training and certification for operations, team rehearsals of operations processes, verification of MOS interfaces, and operations readiness testing to verify the MOS processes, functionality, and operability. These areas are addressed initially through the development of specifications and guidelines that span the breadth of JPL projects. Beyond the guidance is practical assistance through templates for training plans, rehearsals, and readiness tests as well as training modules. The training modules will cover knowledge requirements common to all projects, tools used to conduct operations, and project specific knowledge. Modules will be developed for delivery in tutorial and lecture modes with a future option for on demand, computer based delivery. With the core program in place, it will be easier for projects to afford an effective training and verification effort which can be adapted to the unique attributes of their flight project and improve the risk reduction effort essential to mission success.

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TABLE OF CONTENTS

INTRODUCTION

In the past decade, flight projects have changed their approaches to conducting missions as a result of cost caps and shortened schedules. Some of these changes are new approaches while many others are just scaling back of traditional approaches. The problem with scaling back an effort is that risk scales in the opposite direction. This is precisely the case with the preparations of individuals, teams, interfaces and procedures. Decreased preparation has increased the risk of error. In light of this situation, we have identified the following Statement of Need.

The Mission Management Office needs to reduce risk factors for project success associated with personnel performance, interfaces, operational processes, and system implementations.

We will propose a new approach for the Mission Management Office that can be effective in the current climate of small, innovative, low cost space missions.

The traditional approach to training and operations development cannot be sustained in today's austere environment. Attempting to do so has led to two

unacceptable scenarios. The first is to delay funding for project training and then expect to hire a training engineer who can miraculously produce a trained team with one or two operations readiness tests. This approach ignores the need for individuals to learn what their roles are and the need for teams to practice their procedures and interactions with other teams to establish the timing of their operations processes as well as the time margins that are available (or not) for them to respond to anomalous conditions. (Olson, pp 4)

The second scenario attempts to combine dissimilar functions with similar names. The pitfall that has been encountered here is that the individual chosen to lead the effort has a strong background in only one aspect of the combined program and thus fails to address project critical elements of other program aspects. The result is an unacceptable level of risk in a key aspect of project preparation for mission operations. Both of these scenarios result from common organization thinking that solving the current learning crisis is more important than improving the process and preventing a recurrence of the crisis. (Conner, pp 6)

A third scenario is available to avoid the problems recently encountered. This third scenario is to develop a very clear and extensive infrastructure for operational preparations. Developing this third scenario is the focus of our paper. First we discuss the efforts needed to develop the infrastructure. The areas of emphasis are Individual (Position) Operations Training, Operations Interface and Procedure Development, Flight Team (System) Operations Training, Personnel Certification, Interface and Procedure Verification, and Operations Readiness Testing. Next we discuss our approach and rationale for applying resources to achieve effective implementation of our proposal. Finally, we address the crucial area of compatibility with and support of JPL processes that are at the core of good practices in preparing for and conducting successful mission operations.

Figure 1- Training Process

PROPOSED EFFORT

A Flight Project can satisfy the need to "reduce risk factors for project success associated with personnel performance, interfaces, operational processes, and system implementations" by following JPL's "Engineer the MOS" process. Implementation is a non-trivial undertaking. It helps to take advantage of past implementations and the lessons they provide. It also helps process implementation to have on hand standardized practices and standards of performance, which have come from successful missions and which can be adapted to new missions without recreating everything from scratch. To this end, we are proposing to establish an infrastructure to infuse needed preparation into a strong implementation of two critical elements of the "Engineer the MOS" process: validation and verification.

Validation, or ensuring we are building the right system (Leibrandt, pp 9), benefits from standards and standardization of Individual Training, Team Training and Interface and Procedure Development. This benefit derives from having captured the right approach for these constituents in our MOS development in standards and standardization. Thus having shown that we can rely on these as being the right system constituents, we do not have to reconfirm or revalidate their input.

Similarly, verification, or ensuring we are building the system right (Leibrandt, pp 9), benefits from standards and standardization in Personnel Certification, Interface and Procedure Verification, and Operations Readiness Testing. Again, the benefits derive from having captured a significant amount of the right way to implement these constituents in standards and standardization. Consequently, the effort required to develop adequate verification of personnel, procedures, and systems is reduced, consistent with the current limited funding and short schedule environment.

By developing an infrastructure of standards and standardization for individual training and certification, interface and procedure development and verification, and system training and readiness testing, we reduce the effort to develop inputs for two key deliverables in the "Engineer the MOS" process: the Test, Training, and Validation (TT&V) Plan and the Flight Operations Plan. (Scott, 2002)

Individual Operations Training

Effective individual operations training is a key to risk reduction because it improves an individual's knowledge, understanding and proficiency for operations thus enabling him/her to recognize and correct, or at least adapt to, shortfalls in existing interfaces, processes and implementations as well as respond to anomalies. To be effective, the scope of individual training must span basic understanding of space exploration and mission operations, operations processes and tools, and specific missions and spacecraft systems. For this reason, it is often more cost effective to search out experienced personnel who don't require training and who can mentor new personnel in the minimum essentials they need to get by in their jobs. This approach is not without risk because it lacks the structure and standardization that can ensure that all the essentials are covered and that critical knowledge or skills don't fall through the crack. To mitigate this risk, we are proposing as our first priority to establish a core set of resources which projects can tap into for individual operations training. Included in these resources will be requirements for a project's team to use in designing the training program for team members. Along with the requirements will be guidelines for designing and developing a training program that satisfies the requirements to aid the team leads who may have little training experience yet who traditionally are assigned this responsibility for their team. An additional aid will be a template of a team training plan with boilerplate content that can be adapted to project specific needs with minimal effort. The resources established will not be limited to assistance in developing a team training plan which support the MOS TT&V Plan, but will include actual training modules which address fundamentals common to all projects and training modules on tools, processes, systems, and other operational topics which are easily tailored to address project uniqueness. A basic precept of the training module development is the use of the Adult Learning Model that includes the practical application of training to the learner's environment and active learner participation. (Conner, pp 15) In the case of operations training, this implies training in the implementation of actual procedures and interfaces for realistic scenarios. A consequence of this is to establish our operations interface and procedure development task as the second priority for initiation right after the individual operations training task.

Operations Interface and Procedure Development

As a systems engineering effort, Section 314, the Mission Systems Engineering Section, appropriately leads the operations interface and procedure development. The focus of this effort will be to establish a comprehensive library of procedure and interface templates that are applicable to flight operations at JPL. The documents would contain information common to all projects and guidance for tailoring the documents to a specific project. They would be consistent as far as scope and content to facilitate adaptation by any project and use by personnel moving from one project to another. A logical accompaniment to these generic procedure and interface documents would be a standard for preparation which specifies the scope of each type of document, their format, level of detail and normal content. Such a guide would serve as a checklist to aid in ensuring complete coverage of operational processes and interfaces without unnecessary overlap between documents. Completion of these first two tasks puts us in a position to undertake the third task of flight team operations training

which builds on having procedures, interfaces, and personnel who are trained to implement them.

Flight Team Operations Training

While Flight Team training utilizes active learner involvement and practical experience of the adult learning model, as does individual training, the perspective is different in that we are concerned with performance as a system rather than as individuals. (Conner, pp 15) While individuals may be quite proficient in their individual roles, their training cannot always anticipate the response of others and it is the development of this interplay that is the focus of Flight Team training. Again, it is important to establish a core set of resources that projects can tap into for their Flight Team training development. The initial element of the resource set will be requirements for the development of Flight Team training accompanied by guidelines for designing and developing a training program which will be documented in the Project's TT&V Plan. In direct support of the Training section of the TT&V Plan, we will develop a training plan template with comprehensive boilerplate content that can be adapted to the Project's unique characteristics. This will include scripts for rehearsals and other process/scenario exercises as well as basic learning modules on subject matter that is of interest to a majority of the Flight Team rather than being applicable to individual positions. Once we have a core set of resources in place for individual training, interface and procedure development, and team training, our priority would be to provide a framework that projects can use to verify the results of their efforts.

Position Certification

Verification that an individual has been satisfactorily trained is completed and documented through the Position Certification process. This is a generally accepted and understood activity within JPL flight project operations, but it does not have a well-defined specification that can be used by all projects. Establishing a specification or set of requirements that can be used by all flight projects to maintain a consistency in the standard against which training effectiveness is measured will be the first objective in this part of our effort. With the specification we will develop a certification plan template that can be adapted for each specific flight project to provide the appropriate authority with guidance in how to implement the certification process. As with the other plans we will develop, the certification plan will contain extensive boilerplate to make the adaptation an easy manner for specific flight projects. The content of the certification plan will contribute to development of the project's TT&V Plan.

Operations Interface and Procedure Verification

Because the use of good procedures is so important to training, the procedure and interface verification effort is of nearly the same priority as strengthening the certification process. A stronger verification effort has been evident at JPL for sometime, which is our rationale for addressing certification first in our proposal. However, we feel it is still warranted to see if there aren't ways to streamline the verification process without sacrificing effectiveness. The standardization effort we have already proposed may help two ways. First, with standardized interfaces and procedures, re-verification is easier because you only have to verify where details have changed materially. Second, with standardized interfaces and procedures documented in a library, they are ready for verification much earlier in the project development process leading to less of an impact on development schedules because the verification can be started earlier and spread out over more time for a lessened impact on workload. We would propose then that this effort review these concepts and develop a standard plan input to project verification efforts that take advantage of work already done to do verification of interfaces and procedures in a smarter and more efficient manner. Earlier verification also has an advantage in that it removes a major difficulty for effective operations readiness testing: having complete and verified procedures and interfaces to test as part of specific Project MOS demonstrations of readiness to conduct operations.

Operations Readiness Testing

The face of operations readiness testing has fluctuated over the last decade or more as project budgets, schedules, and focus has fluctuated. Plans and procedures have been written, but not always followed because of changing constraints. A key emphasis of this effort is to develop a workable approach to operations readiness testing that is easily adapted to every flight project without sacrificing the desired effectiveness and contribution to the projects Verification effort. The starting point will again be a set of requirements to specify the operations readiness testing effort. A plan template, which would provide guidance and an approach for conducting readiness testing as a supportive effort of the Project's Validation activity, will be a necessary accompaniment to the requirements. Again, we will include generic content that can be easily adapted to a specific project to form the basis for input to the Project's TT&V Plan. The content would include detailed script templates for ORTs and databases that can be tailored for projects to track progress of individual training and certification, development and verification of interfaces and procedures, and satisfaction of objectives for rehearsals and ORTs. We anticipate that by implementing this effort and establishing a core support capability, which can be used by all projects, we can positively impact the risk posture of projects and achieve more effective utilization of already limited resources in the areas of training and verification.

RESOURCES

The suite of resources to be applied to this effort has not been generally teamed together at JPL in the past. The urgent need of the near term flight projects at JPL for guidance and economy in preparing teams for operations is a call for new partnerships that can respond to the need. Mars Exploration Rovers (MER), Mars Reconnaissance Orbiter (MRO) and Deep Impact (DI) are projects on the horizon with limited budgets to reduce the risk from poor performance, processes, and implementations. It is important then to pull together the right expertise to establish the infrastructure that can help reduce these risks.

Projects have often utilized Systems Engineers, Training Engineers, and Operations Engineers as part of their MOS development. Therefore, teaming these resources to develop the infrastructure desired is not new. The novelty will be in teaming instructional developers along with the technical resources to develop and deliver "e-learning" with the traditional engineering support. This new facet will be incrementally added to the initial cadre until the full capability needed for the infrastructure development is assembled. The team makeup will be adjusted in moving from the development phase to the sustaining phase that includes maintenance and adaptations for specific projects.

The development phase will begin with a core of three full time equivalents (FTE) members with experience/expertise in project flight operations, rehearsals and simulations, systems engineering, and instruction. This level of effort is sized to be able to put in place the baseline standards, templates, and content boilerplate for individual training and certification, interface and procedure development and verification, and system training and readiness testing in time to be used by MER, MRO, and DI.

As the baseline documentation is developed, the specific learning modules that are needed will be identified. Instructional design and development resource will begin to be phased onto the team. The learning module development, while somewhat generic, will also solicit input from MER, MRO, and DI simulation Director/Training Engineer/system Engineer as they join these projects and begin to adapt the baseline material for their project. The close collaboration of our team and these key project players is integral to our team's role in the significant JPL processes related to flight projects.

PROCESSES

We strive to be consistent with and support the "Engineer the MOS" and "Provide Operations Services" processes and the developing process "Train Flight Operations Teams". Refinement of present process-supporting procedures will naturally be a resultant product leading the MOS with greater surety towards operations readiness. The proposed infrastructure developed by our team will provide input to key elements of a flight project's TT&V Plan and its Flight Operations Plan. The infrastructure will provide a substantive input to the foundation for successful "Engineer the MOS" and "Provide Operations Services" processes in future projects' planning for adequate resources to reduce risk in the areas we are concentrating on.

Historically participation in training, procedure development, verification and readiness testing has been inadequately scoped or deferred in contracts and Work Package Agreements (WPA). The infrastructure we will develop provides the basis for Request for Proposal (RFP) content and WPA guidelines to adequately address the level and timing of such training, development, and verification efforts. With adequate guidance, proposals can appropriately scope participation in these risk reduction activities with reliance upon our infrastructure factored into the calculations. Properly scoping participation enables project managers to make informed assessments of levels of risk and risk mitigation that can be planned into the project funding profile.

With an infrastructure in place, we can provide early support to project planning for adequate efforts to contribute to successful process implementation without added costs to the project. Clearly, our proposed infrastructure provides a cost effective contribution of value added constituents of key JPL processes from the early planning phases through process completion.

CONCLUSION

By properly preparing for mission operations, it is possible for a project to mitigate the risks from non-optimal personnel performance, interfaces, operational processes, and system implementations. The challenge is to find a new way to prepare for operations that is consistent with new budgets and schedules. We have concluded that development of an infrastructure that supports thorough and correct development of the MOS by providing standardized practices with standards of performance is the most cost effective approach. We discussed the effort involved for Individual (Position) Operations Training, Operations Interface and Procedure Development, Flight Team (System) Operations Training, Personnel Certification, Interface and Procedure Verification, and Operations Readiness Testing leading to risk mitigation. We also examined the appropriate application of resources to be successful in the proposed effort. Then we addressed consistency with and contributions to the JPL processes that are key to successful space exploration missions.

The institutional investment is moderate, measured, and can be adjusted to a changing environment. The proposed effort will address key mission risk areas and is designed to blend with limited project resources to provide risk reduction in areas of significant vulnerability.

Implementation of this effort will provide benefits now to MER, MRO, and DI as well as future projects at JPL by providing a broad based infrastructure to support key elements of JPL processes. The infrastructure support can significantly reduce project risk by providing a greater likelihood of success of personnel performance, interfaces, operational processes, and system implementations.

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